Economizer Applications in Dual-Duct Air-Handling Units

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ABSTRACT

This paper provides analytical tools and engineering methods to evaluate the feasibility of the economizer for dual-duct air-handling units. The results show that the economizer decreases cooling energy consumption without heating energy penalties for dual-fan, dual-duct air-handling units. The economizer has significant heating energy penalties for single-fan, dual-duct air-handling units. The penalties are higher than the cooling energy savings when the cold airflow is less than the hot airflow. Detailed engineering analyses are required to evaluate the feasibility of the economizer for single-fan, dual-duct systems.

INTRODUCTION

The economizer is widely acknowledged as one of the popular energy conservation measures. It eliminates or reduces mechanical cooling by using free cooling. For a single-duct system, the economizer reduces mechanical cooling with no heating penalties. For a dual-duct system, however, heating energy penalties may exist. Liu et al. [1997] pointed out that the heating energy penalty is often higher than the cooling energy savings for single-fan, dual-duct (SFDD) air-handling units, and they developed an advanced economizer algorithm to solve the economizer operational problems. However, there are no general guidelines or recommendations for the economizer design for dual-duct systems. This paper presents economizer models, performs the energy performance analyses, and develops the design recommendations.

SYSTEM MODELS

The dual-duct system supplies both hot and cold air to each zone, where a terminal box modulates the total airflow rate and/or the mixing ratio of hot and cold air to maintain the room temperature. The dual duct-systems are defined as single-fan, dual-duct (SFDD) systems, where a single fan is used to push air through both hot and cold ducts, and dual-fan, dual-duct (DFDD) systems, where two fans are used to push air through cold and hot ducts, respectively.

<u>Single-Fan, Dual-Duct (SFDD) System</u>

The SFDD system (see Figure 1) includes an economizer, supply and return air fans, a pre-heating coil, and cooling and heating coils. The terminal boxes modulate the cold airflow, the hot airflow, or both to maintain the room air temperature.

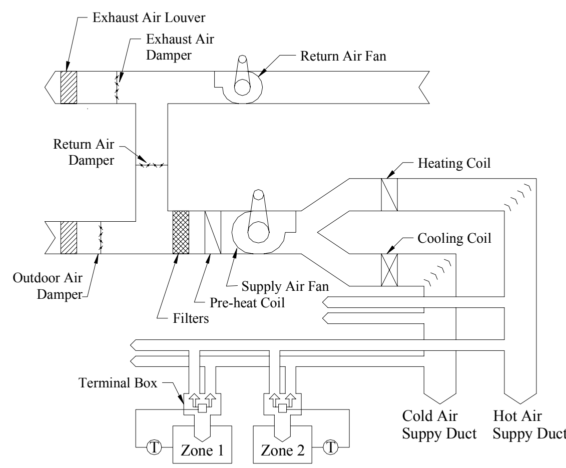

Figure 1. Schematic diagram of the SFDD system

The economizer modulates exhaust air, return air and outside air dampers accordingly to maintain the mixed air temperature at its setpoint. In practice, the mixed air temperature setpoint is slightly lower than the cold air temperature setpoint to avoid the chilled water valve hunting or frequently opening and closing. The action of the exhaust and outside air dampers opposes the return air damper. When the outside air damper is fully open, the return air damper is closed. When the outside air damper is in the minimum open position, the return air damper is totally open.

The economizer can be activated using either outside air temperature (temperature economizer) or outside air enthalpy (enthalpy economizer). The temperature economizer is activated when the outside air temperature is within a predefined range. The enthalpy economizer is activated when the outside air enthalpy is smaller than the return air enthalpy. Both the temperature and enthalpy economizers use the same control sequence after activation. Figure 2 and Equation (1) present the economizer schedules.

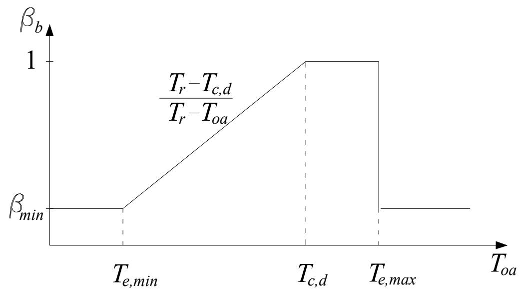

Figure 2. Economizer schedules for the SFDD system

$$\beta_b = \begin{cases} \beta_{\min} & T_{oa} \geq T_{e,\max} \\ 1 & T_{c,d} \leq T_{oa} < T_{e,\max} \\ \dfrac{T_r - T_{c,d}}{T_r - T_{oa}} & T_{e,\min,b} \leq T_{oa} < T_{c,d} \\ \beta_{\min} & T_{oa} < T_{e,\min,b} \end{cases} \quad (1)$$

When the outside air temperature (T_{oa}) is higher than the cold air temperature setpoint ($T_{c,d}$), the economizer uses 100% outside air. When the outside air temperature is lower than the cold air temperature setpoint, the economizer maintains the mixed air temperature at the cold air temperature setpoint. When the economizer is off, the system receives the minimum outside intake.

The minimum economizer temperature, $T_{e,\min,b}$, varies depending on the minimum outside air intake ratio, $\beta_{\min}(m_{oa,\min}/m_d)$.

$$T_{e,\min,b} = T_r + \frac{1}{\beta_{\min}}(T_{c,d} - T_r) \quad (2)$$

The heating and cooling energy consumption depends on economizer cycles, entering air conditions, setpoints of leaving air conditions, and cold and hot airflow rates. When these parameters are given, the heating and cooling energy consumptions can be calculated using energy balance principles [Joo and Liu 2002, under review].

Dual-Fan, Dual-Duct (DFDD) System

The DFDD system (see Figure 3) has two supply fans. Outside air is directly introduced into the cold air duct. When the cold airflow rate is smaller than the outside air intake rate, however, a portion of the outside air is supplied to the hot air duct. Figure 4 and Equation (3) present the economizer schedules.

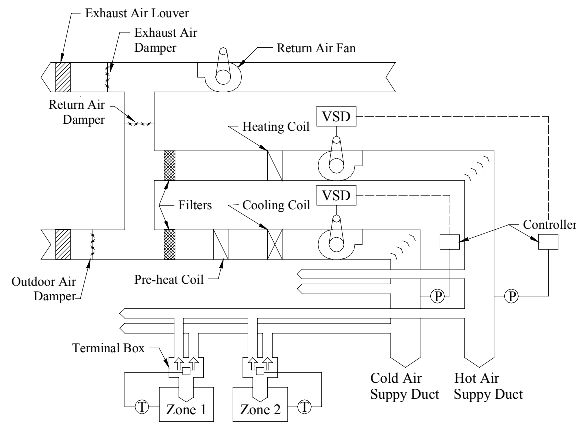

Figure 3. Schematic diagram of the DFDD system

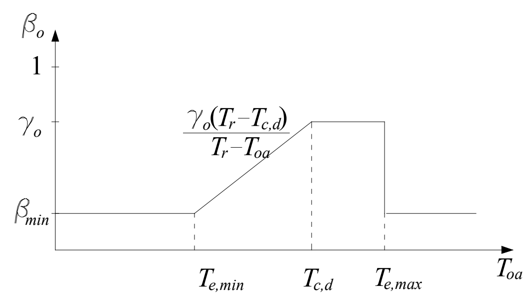

Figure 4. Economizer schedules for the DFDD system

$$\beta_o = \begin{cases} \beta_{\min} & T_{oa} \geq T_{e,\max} \\ \gamma_o & T_{c,d} \leq T_{oa} < T_{e,\max} \\ \dfrac{\gamma_o \cdot (T_r - T_{c,d})}{T_r - T_{oa}} & T_{e,\min,o} \leq T_{oa} < T_{c,d} \\ \beta_{\min} & T_{oa} < T_{e,\min,o} \end{cases} \quad (3)$$

When the outside air temperature is between the maximum economizer temperature ($T_{e,\max}$) and the cold air temperature setpoint ($T_{c,d}$), the outside air is directly supplied into the cold air duct. The cold airflow rate equals the outside airflow rate, and all hot air is from the return air.

When the outside air temperature is between the cold air temperature setpoint and the minimum economizer temperature ($T_{e,\min,o}$), the outside airflow is modulated to maintain the cold deck mixed air temperature at the cold deck setpoint. The hot deck air is from the return air unless the cold airflow ratio (γ_o) is smaller than the minimum outside air intake ratio.

When the outside air temperature is higher than the maximum economizer temperature or lower than the minimum economizer temperature, the economizer is disabled. When the cold airflow ratio is smaller than the minimum outside air intake ratio, outside air is allowed into the hot deck in any schedule.

β_o is an outside air intake ratio (a ratio of the outside airflow to the total airflow), which may differ from the outside air intake ratio of the SFDD system (β_b) because of the dual-fan system's characteristic that the outside air is directly supplied to the cold deck.

The minimum economizer temperature of the DFDD system, $T_{e,\min,o}$, varies depending on $\beta_{\min}$ and γ_o.

$$T_{e,\min,o} = T_r + \frac{\gamma_o}{\beta_{\min}}(T_{c,d} - T_r) \tag{4}$$

The energy consumptions can be calculated using general energy balance principles. Joo and Liu provided the detailed models [Joo and Liu 2002, under review].

ANALYSIS

Economizer performance depends on the following parameters: minimum and maximum economizer temperatures, minimum outside air intake ratios, cold airflow ratios, room conditions, and deck setpoints. The parameter ranges are selected carefully so that simulation results can be directly used and serve as a guideline for engineers.

The temperature economizer is used in this study due to the following reasons: (1) it is more popular than the enthalpy economizer, and (2) both economizers have the same performance after activation.

The economizer is activated when the outside air temperature is between the minimum economizer temperature (20°F or -6.7°C) and the maximum economizer temperature (65°F or 18.3°C). Most operating staffs turn off economizers when the outside air temperature is 32°F (0°C) or lower to avoid potential coil freezing. However, coils can be protected if the return and outside air is well mixed during the economizer cycle. Therefore, the minimum economizer temperature is selected to be 20°F (-6.7°C).

The maximum economizer temperature depends primarily on the outside air moisture contents. For a dry climate, such as New Mexico, the maximum economizer temperature can be as high as the return air temperature. For a humid climate, such as Galveston, TX, the maximum economizer temperature should be limited to 62°F (16.7°C) or lower. To consider general conditions, the maximum economizer temperature is selected to be 65°F (18.3°C).

The minimum outside air intake depends on the building functions. It often varies from 10% (office buildings) to 30% (hospital buildings). At a low outside air temperature, an office building may require 30% outside air intake due to a reduced total airflow rate. Therefore, the simulation is conducted using minimum outside air intakes of 10%, 20% and 30%, respectively.

The partial building load can be expressed using the cold airflow ratio and the supply air temperature. When the cold airflow ratio is 1, the building is in full cooling. When the cold airflow ratio is 0, the building is in full heating.

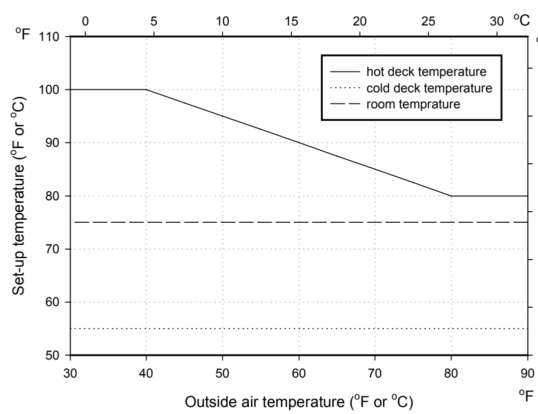

Figure 5. Room and deck operating schedules

Figure 5 presents the room and deck temperature reset schedules. The room conditions are 75°F (23.9°C) and 50% relative humidity. The cooling coil discharge temperature is 55°F (12.8°C). The hot deck temperature is 100°F (37.8°C) when the outside air temperature is 40°F (4.4°C) or lower, and the hot deck temperature is 80°F (26.7°C) when the outside air temperature is 80°F (26.7°C) or higher. The hot deck temperature linearly increases as the outside air temperature decreases when the outside air temperature is between 40°F (4.4°C) and 80°F (26.7°C).

San Antonio Bin data [Degelman 1984] were used for the simulation. The humidity ratio has a very limited impact during the economizer cycle. The results can be used for most climates.

The energy performance is evaluated using potential energy savings per unit total airflow rate. The potential energy savings is also expressed using ratios of savings over 6 Btu/lbm (14 kJ/kg) which is required energy to cool one pound of air from 75^{o}F (23.9^{o}C) and 50% relative humidity (the room design conditions) to 55^{o}F (12.8^{o}C) and 90% relative humidity. If the savings is shown as 0.2 or 20%, for example, the real savings will be 1.2 Btu per pound of air supplied to the system (or 2.8 kJ per 1 kilogram of air).

<u>Economizer and the SFDD System</u>

Figure 6 presents contour lines of cooling energy savings of the economizer for the SFDD system. The chart shows three different outside air intake ratios. The abscissa represents the outside air temperature (T_{oa}). The ordinate represents the cold airflow ratio (γ_b). The different cold airflow ratios represent different load conditions. For example, γ_b=0 is 100% heating and γ_b=1 is 100% cooling.

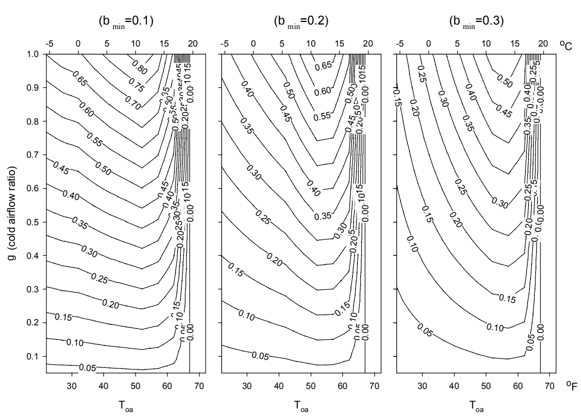

Figure 6. Cooling energy savings of the economizer in the SFDD system

The economizer reduces the cooling energy consumption. The more the cold air is supplied, the larger the savings are for the same ambient temperature. The mixed air temperature of the economizer applied is lower than that without the economizer.

The lower the minimum outside intake ratio, the higher the energy savings are for the same ambient and load conditions. The temperature difference between the mixed air temperature without the economizer and with the economizer is larger for the lower minimum outside intake ratio.

When the outside air temperature is higher than the cold deck setpoint 55^{o}F (12.8^{o}C), the savings decrease as the outside air temperature increases. The reason is that the temperature difference between the mixed air temperature without the economizer and with the economizer decreases as the ambient temperature increases.

Figure 7 presents contour lines of heating energy savings of the economizer. The economizer increases the heating energy consumption. The more the hot air is supplied, the larger the penalties are for the same ambient temperature. For example, when the outside air temperature is 35^{o}F (1.7^{o}C), the mixed air temperature is 67^{o}F (19.4^{o}C) without the economizer. When the economizer is used, it is 55^{o}F (12.8^{o}C). Therefore, the heating coil has to warm up air from 55^{o}F (12.8^{o}C) to the hot deck setpoint due to the economizer operation.

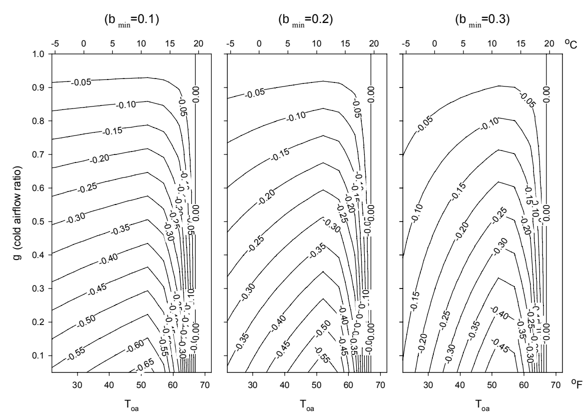

Figure 7. Heating energy penalties of the economizer in the SFDD system

The lower the minimum outside intake ratio, the higher the penalties are for the same ambient and load conditions. When the minimum outside air ratio is lower, the mixed air temperature is higher without the economizer. The mixed air temperature under the economizer operation maintains the same regardless of different minimum outside air intake ratios.

When the outside air temperature is higher than the cold deck setpoint 55^{o}F (12.8^{o}C), the penalties decrease as the outside air temperature increases. The temperature difference between the mixed air temperature without the economizer and with the economizer decreases as the outside air temperature increases.

Figure 8 shows the total thermal energy savings of the economizer calculated as the sum of the heating energy penalties and the cooling energy savings. When the hot airflow rate is larger than the cold airflow rate, the savings are negative. When the cold airflow rate is larger than the hot airflow rate, the savings are positive. The smaller minimum outside intake ratio shows higher savings when the cold airflow rate is larger than the hot airflow rate, and shows higher penalties when the hot airflow rate is larger than the cold airflow rate for the same ambient and load conditions.

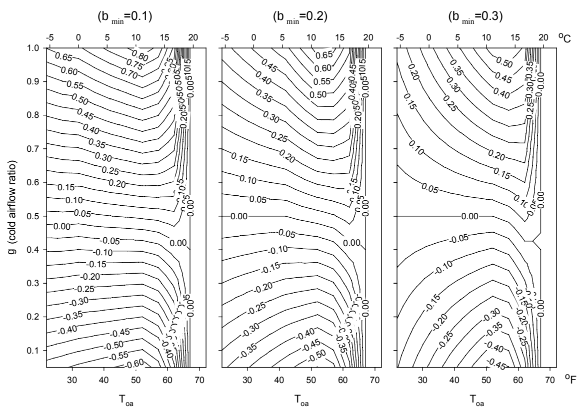

Figure 8. Total energy savings of the economizer in the SFDD system

When the outside air temperature is low, the cold airflow can be higher or lower than the hot airflow rate depending on the building characteristics. If the cold airflow is higher than the hot airflow, the economizer can be installed to decrease the overall thermal energy consumption. However, if the cold airflow is lower than the hot airflow, the economizer should not be installed. Detailed engineering analyses are required to justify the feasibility of the economizer for each case.

Economizer and the DFDD System

Figure 9 presents contour lines of the cooling energy savings of the economizer for the DFDD system. The economizer saves cooling energy when the cold airflow is larger than the outside air intake. Below the zigzag line, there are no cooling energy consumptions because the cold deck mixed air temperature is lower than the cold deck setpoint. The higher the cold airflow ratio, the larger the energy savings are for the same ambient temperature. The economizer is less effective when the minimum outside air intake ratio is high.

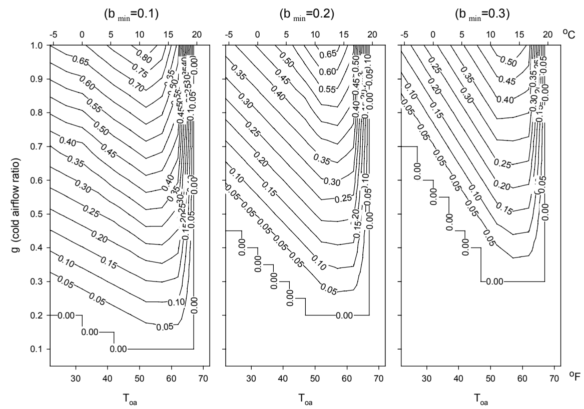

Figure 9. Cooling energy savings of the economizer in the DFDD system

For a typical office building, the outside air intake ratio is from 0.1 to 0.2. The cooling energy savings is up to 30% for $\beta_{\min}$ =0.1 and up to 20% for $\beta_{\min}$ =0.2 when the outside air temperature is below 60°F (15.6°C).

The economizer has no heating energy savings or penalties for the DFDD system. The return air is directly introduced to the hot deck. The heating coil inlet temperature is the same as the return air temperature regardless of the economizer use when the cold airflow ratio is higher than or equal to the outside air intake ratio. When the cold airflow ratio is lower than the outside air intake ratio, a portion of outside air is supplied to the hot deck. The economizer is disabled, and only the minimum outside air is allowed to the system.

Economizer and Retrofit

An economizer retrofit is not recommended for the SFDD system in typical commercial buildings. However, it may be cost effective for the DFDD system. When the SFDD system is retrofitted to the DFDD system, the economizer should be retained.

Figure 6 presents cooling energy savings of adding an economizer when the SFDD system is converted to the DFDD system. The savings are generally 5% to 40% depending on ambient and load conditions.

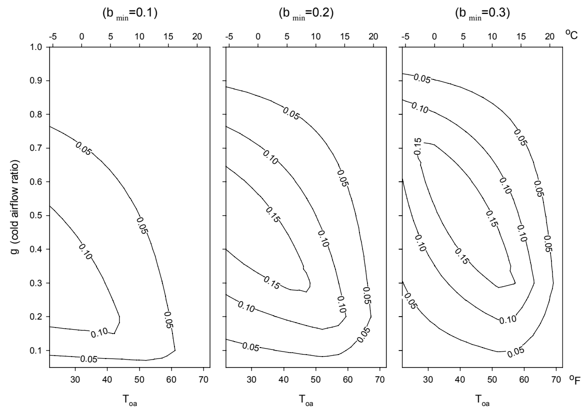

Figure 10. Heating energy savings of retrofitting the SFDD system to the DFDD system and adding an economizer

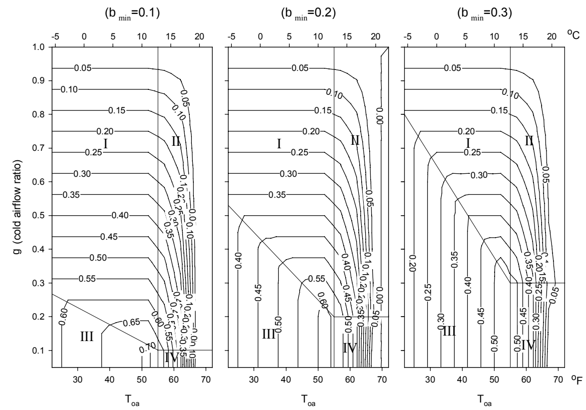

Figure 11. Heating energy savings of retrofitting the SFDD system with the economizer to the DFDD system and keeping the economizer

Figure 10 presents contour lines of heating energy savings of adding an economizer when the SFDD system is converted to the DFDD system. The savings are generally 5% up to 15%. At low ambient temperatures, savings are low for the high outside air intake ratio due to the pre-heating penalties. The more outside air the system takes, the more pre-heating penalties it generates.

For example, when the outside air temperature is 50^{o}F (10.0^{o}C), the cold airflow ratio is assumed to be 0.4. The minimum outside air intake ratio is 0.2. Then, the cooling energy savings is 25% (Figure 6). The heating energy savings is 12% (Figure 10). The total thermal energy savings is 37% or 2.22 Btu/lbm.

If the SFDD system has the economizer, no cooling energy savings can be achieved when it is converted to the DFDD system. Neither system requires cooling energy.

Figure 11 presents heating energy savings of retrofitting the SFDD system to the DFDD system when the economizer remains. The savings range from the maximum of 50% to 70% depending on outside air intake ratios. The heating energy savings are divided into four regions. The cold deck temperature setpoint line divides Region I and Region II, and it also divides Region III and Region IV. The preheating energy penalty line divides Region I and Region III (below this line, pre-heating penalties occur in the DFDD system because the mixed air temperature is lower than the cold deck temperature). The minimum outside intake line divides Region II and Region IV.

Region I: the heating energy savings only depends on cold airflow ratio. The hot deck mixed air temperature is constant at 55^{o}F (12.8^{o}C) for the SFDD system and at 75^{o}F (23.9^{o}C) for the DFDD system. The lower the cold airflow ratio, the higher the savings are.

Region II: the heating energy savings decrease when the outside air temperature is close to 65°F (18.3°C). The temperature difference between the hot deck air temperature and the mixed air temperature decreases for the SFDD system, even though the temperature difference between the hot deck air temperature and the hot deck inlet mixed air temperature remains constant for the DFDD system.

Region III: the savings depends on the outside air temperature and the minimum outside intake ratio. As the outside air temperature decreases, the savings decrease. The lower the minimum outside air intake ratio, the higher the savings are for the same outside air temperature.

Region IV: the cold airflow rate is lower than the outside intake rate. A proportion of outside air is introduced into the hot deck. The heating energy savings depend on the outside air temperature and the outside air intake ratio. The savings drastically decrease when the outside air temperature is close to 65°F (18.3°C).

Figures 6 through 11 present the potential energy savings under the pre-defined room temperature and deck schedules. If actual room conditions or actual cold and hot deck temperatures are different from the schedules, the potential energy savings can still be determined using Figures 6 through 11, provided that the cold airflow ratio is corrected using the following equations.

i) Room temperature correction

$$\gamma_1 = \gamma_2 + \frac{T_{r1} - T_{r2}}{T_c - T_h} \tag{5}$$

ii) Cold deck temperature correction

$$\gamma_1 = \gamma_2 \times \frac{T_{c2} - T_h}{T_{c1} - T_h} \tag{6}$$

iii) Hot deck temperature correction

$$\gamma_1 = \frac{T_{h2} - T_{h1} + \gamma_2 (T_c - T_{h2})}{T_c - T_{h1}} \tag{7}$$

APPLICATION

The potential hourly energy savings can be determined using Figures 6 through Figure 11. To determine the hourly energy savings, the total building airflow rate, the outside air intake rate, the cold airflow rate, the outside air temperature, the room air temperature, and the cold and hot air temperature must be given. With the given outside air temperature, the outside air intake ratio and cold airflow ratio are used to determine the percentage of energy savings in the charts.

Typically, room and deck temperature corrections are required during the process. These corrections, using Equation (5) through Equation (7), lead a new cold airflow ratio that yields a new savings percentage with which the actual hourly energy savings can be calculated.

Hourly energy savings, ΔE_{hr} [Btu/hr], can be calculated with the total building airflow rate and the percentage of savings in the charts as the following equation.

$$\Delta E_{hr} = \dot{m} \times \varphi \times 6(Btu/lbm) \tag{8}$$

For example, a hypothetical commercial building has a DFDD system and the floor area of 100,000 ft^2 (9290 m^2). The system operates with the total building airflow rate of 100,000 ft^3/min (47.2 m^3/s). The minimum outside intake ratio is 20%, and the cold airflow ratio is 0.5. The outside air temperature is 55^{o}F (12.8^{o}C). The cold deck temperature is set at 55^{o}F (12.8^{o}C), and the hot deck temperature is set at 92.5 ^{o}F (33.6^{o}C). As a result, the total cooling energy savings for adding an economizer is 22% (See Figure 9). The total cooling energy savings is 594,000 Btu/hr (174.1 kW) using Equation (8).

If the cold air temperature is reset to 60^{o}F (15.6^{o}C), the cold airflow ratio is 0.57 by Equation (6). The cooling energy savings is 27%. The total cooling energy savings is 729,000 Btu/hr (213.6 kW). The savings for the room temperature changes or the hot air temperature resets can be calculated as the same way using Equation (5) or (7).

The annual potential energy savings can be calculated using Equation (9) based on hourly savings and the number of operating hours. The cold airflow ratio has to be estimated depending on building characteristics. Based on the bin temperature and the estimated cold airflow ratio, the percentage of energy savings can be determined using Figures 6 through 11.

$$\Delta E_{yr} = \sum_i \left(\Delta E_{hr,i} \times N_i \right) \tag{9}$$

CONCLUSION

Models for thermal energy consumptions are developed to investigate the economizer effects for the SFDD system and the DFDD system. A method is developed to determine the potential energy savings.

The economizer reduces both the heating and cooling energy consumption for the DFDD systems. The economizer may increase or decrease the overall thermal energy consumption depending on the building characteristics for the SFDD systems. The detailed engineering analyses are required to justify the installation of the economizer for each case. When the SFDD system is converted to the DFDD system, the economizer should be retained.

NOMENCLATURE

c_p	= Specific heat for dry air (Btu/(lbm ^{o}F) or J/(kg ^{o}F))
E	= Energy consumption (Btu/lbm or kJ/kg)
h	= Air enthalpy (Btu/lbm or J/kg)
$\dot{m}$	= Airflow rate (lbm/hr or kg/s)
ΔE	= Energy savings (Btu/hr or kW, Btu/yr or kWh/yr)
T	= Air temperature (^{o}F or ^{o}C)
β	= Outside air intake ratio ($\dot{m}_{oa} / \dot{m}_d$)
γ	= Cold airflow ratio ($\dot{m}_c / \dot{m}_d$)
φ	= Energy savings (non-dimensional)

Subscripts

b	= Base case system, single-fan, dual-duct constant volume system
c	= Cooling, cold deck
d	= Designed
dew	= Dew point
e	= Economizer
f	= Fan
h	= Heating, hot deck
m	= Mixed
max	= Maximum
min	= Minimum
o	= Optimized system, dual-fan, dual-duct constant volume system
oa	= Outside air
p	= Preheating
r	= Room air

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Joo, I. and Liu, M., 2001. "Performance Analysis of Dual-Fan, Dual-Duct Constant Volume Air-Handling Units", ASHRAE under review.

Homes produced with airtight duct systems (around 15% savings in Htg and Cooling Energy)

Palm Harbor Homes	22,000
Southern Energy Homes	8,000
Cavalier Homes	1,000
	= = =
Subtotal	31,000

Technical measures incorporated in BAIHP homes include some or many of the following features - better insulated envelopes (including Structural Insulated Panels and Insulated Concrete Forms), unvented attics, “cool” roofs, advanced air distribution systems, interior duct systems, fan integrated positive pressure dehumidified air ventilation in hot humid climates, quiet exhaust fan ventilation in cool climates, solar water heaters, heat pump water heaters, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems.

HOMES BY THE FLORIDA HOME ENERGY AND RESOURCES ORGANIZATION (FL.H.E.R.O.)

Over 400 single and multifamily homes have been constructed in the Gainesville, FL area with technical assistance from FL H.E.R.O. These homes were constructed by over a dozen different builders. In this paper data from 310 of these homes is presented. These homes have featured better envelopes and windows, interior and/or duct systems with adequate returns, fan integrated positive pressure dehumidified air ventilation, high efficiency right sized heating/cooling equipment, and gas fired combo space/water heating systems. The innovative outside air (OA) system is described below.

The OA duct is located in the back porch (Figure 1) or in the soffit (Figure 2). The OA is filtered through a 12"x12" filter (which is readily available) located in a grill (Figure 3) which is attached to the OA duct box. The flex OA duct size varies depending on the system size - 4" for up to 2.5 tons, 5" for 3 to 4 ton and 6" for a 5 ton system. The OA duct terminates in the return air plenum after a manually adjustable butterfly damper (Figure 4).

Figure 1 OA Intake Duct in Back Porch

Figure 2 OA Intake Duct in Soffit

Figure 3 Filter Backed Grill Covering the OA Intake

Figure 4 Butterfly Damper for OA control

The damper can be set during commissioning and closed by the homeowner in case the OA quality is poor (e.g. forest fire). This system introduces filtered and conditioned ventilation air only when the cooling or heating system is operational. The ventilation air also positively pressurizes the house. Data on the amount of ventilation air or positive pressurization is not available from a large sample of homes. A few measurements indicate that about 25 to 45 cfm of ventilation air is provided which pressurizes the house in the range of +0.2 to +0.4 pascals.

Measured Home Energy Ratings (HERS) and airtightness on these FL. H.E.R.O. homes is presented next in figures 5 through 8. Data is presented for both single family detached (SF) and multifamily homes (MF). See Table 2 below.

Table 2. Summary statistics on FL.H.E.R.O. Homes
n = sample size

	SF	MF
Median cond area	1,909	970
% constructed with 2x4 frame or frame and block	94%	100%
Avg. Conditioned Area, ft^2	1,993 (n=164)	1,184 (n=146)
Avg. HERS score	87.0 (n=164)	88.0 (n=146)
Avg. ACH50	4.5 (n=164)	5.2 (n=146)
Avg. Qtot (CFM25 as %of floor area)	6.9% (n=25)	5.0% (n=72)
Avg. Qout (CFM25 as %of floor area)	3.0% (n=15)	1.4% (n=4)

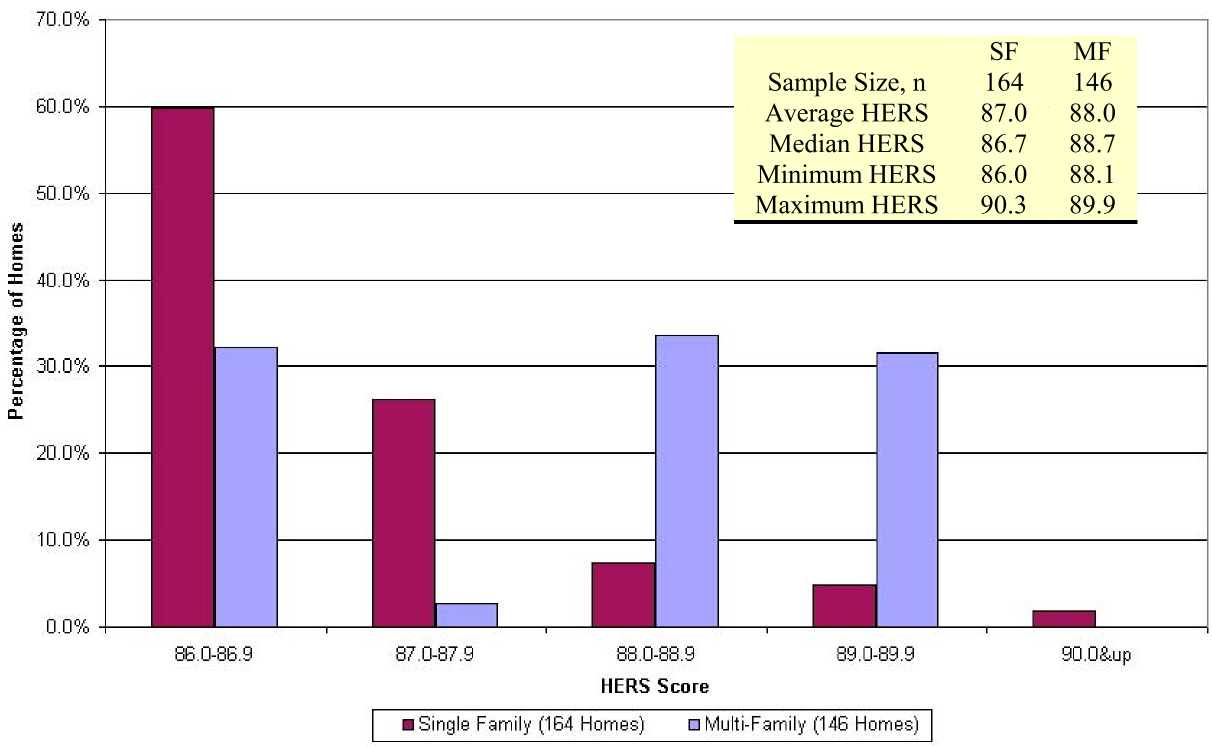

Figure 5 HERS Scores for FL H.E.R.O. Homes

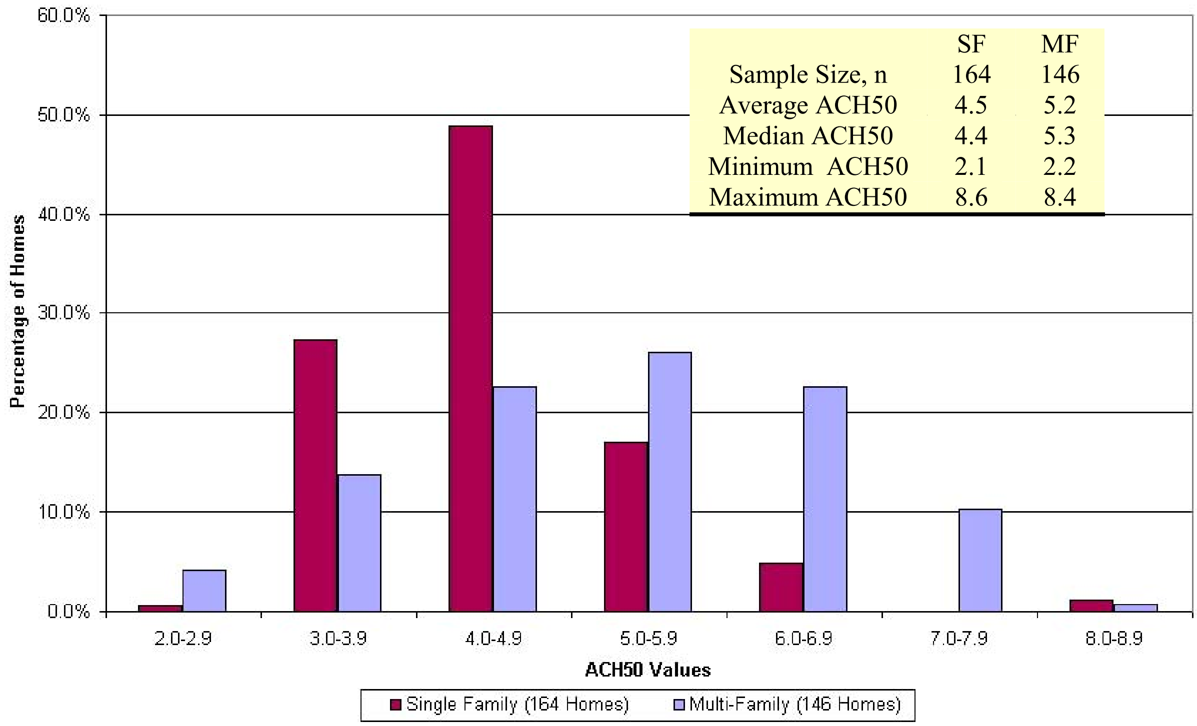

Figure 6 ACH50 Values for FL H.E.R.O. Homes

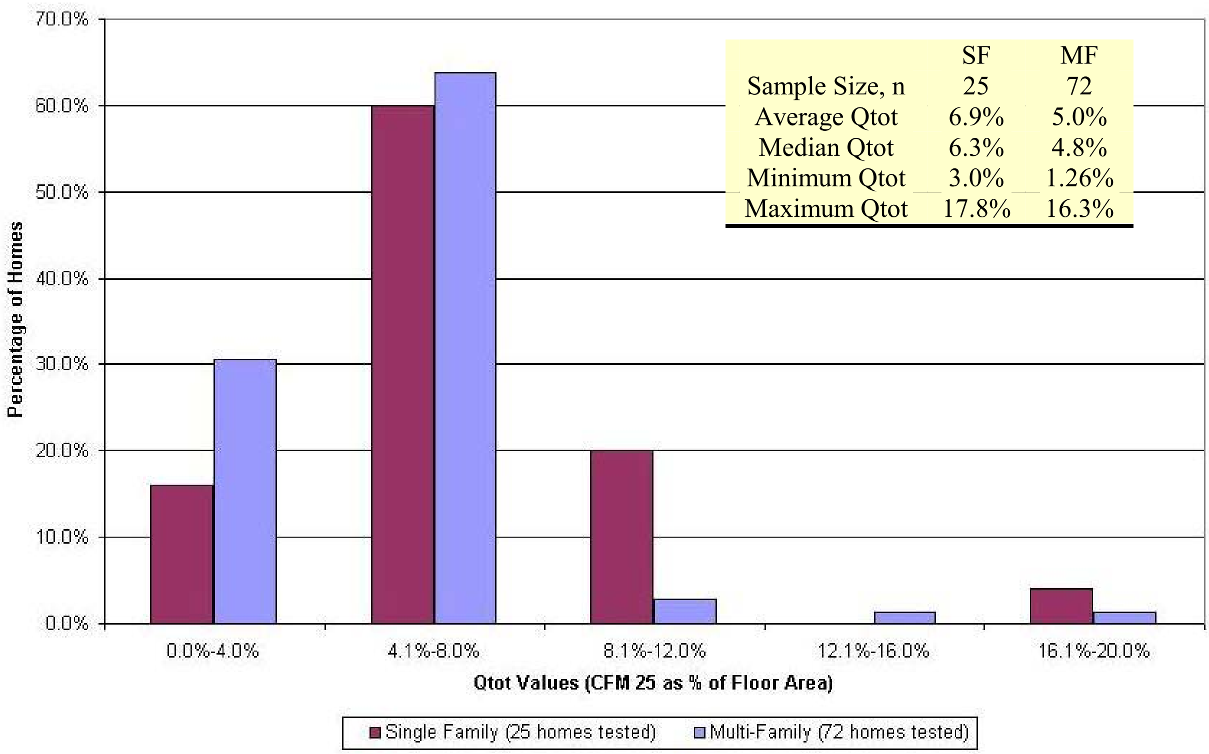

Figure 7 Qtot Values for FL H.E.R.O. Homes

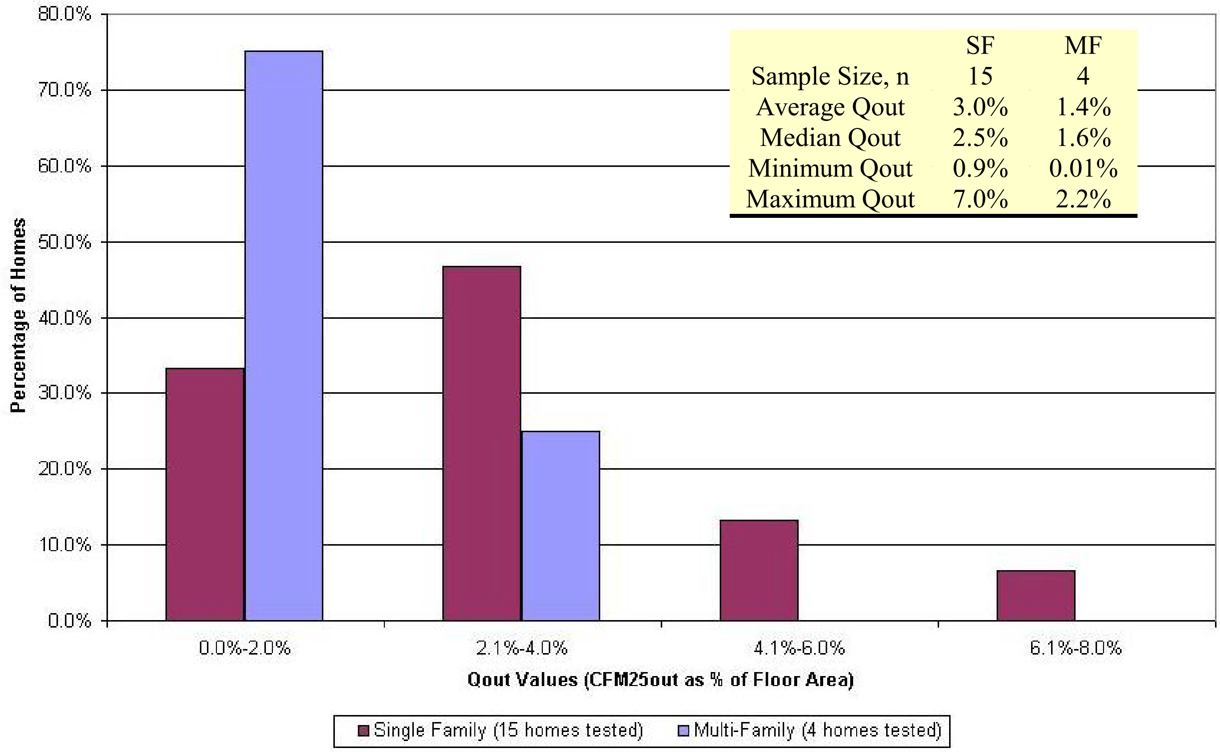

Figure 8 Qout Values for FL H.E.R.O. Homes

Data is available for other typical non BAIHP, new Florida homes (FPL , 1995 and Cummings et al, 2001). The FPL study had a sample size of over 300 single family homes and the median Qout was 7.5% , three times that of the FL. H.E.R.O. homes. In the Cummings study of 11 homes the measured average values were : ACH50= 5.7, Qtot=9.4% and Qout=4.7%. Although the sample sizes are small the FL. H.E.R.O. homes appear to have significantly more airtight duct systems than typical homes.

The remainder of the paper presents status of other tasks of the BAIHP project.

OTHER BAIHP TASKS

Moisture Problems in HUD code homes

The BAIHP team expends considerable effort working to solve moisture problems in existing manufactured homes in the hot, humid Southeast.

Some manufactured homes in Florida and the Gulfcoast have experienced soft walls, buckled floors, mold, water in light fixtures and related problems. According to the Manufactured Housing Research Alliance (MHRA), who we collaborate with, moisture problems are the highest priority research project for the industry.

The BAIHP team has conducted diagnostic tests (blower door, duct blaster, pressure mapping, moisture meter readings) on about 40 such problem homes from five manufacturers in the past two years and shared the results with MHRA. These homes were newly built (generally less than 3 years old) and in some cases just a few months old when the problems appeared. The most frequent causes were:

- Leaky supply ducts and/or inadequate return air pathways resulting in long term negative pressures.
- Inadequate moisture removal from oversized a/c systems and/or clogged condensate drain, and/or continuous running of the air handler fan.
- Presence of vinyl covered wallboard or flooring on which moist air condenses creating mold, buckling, soft walls etc.
- Low cooling thermostat set point (68-75F), below the ambient dew point.
- Tears in the belly board and/or poor site drainage and/or poor crawlspace ventilation creating high rates of moisture diffusion to the floor.

Note that these homes typically experience very high cooling bills as the homeowners try to compensate for the moisture problems by lowering the thermostat setpoints. These findings have been reported in a peer reviewed paper presented at the ASHRAE IAQ 2001. conference (Moyer et al)

The Good News:

As a result of our recommendations and hands-on training, BAIHP partner Palm Harbor Homes (PHH) has transformed duct design and construction practices in all of its 15 factories nationwide producing about 11,000 homes/yr. All Palm Harbor Home duct systems are now constructed with mastic to nearly eliminate air leakage and produced with return air pathways for a total cost of <$10/home!! The PHH factory in AL which had a high number of homes with moisture problems has not had a single problem home the past year!

Field Monitoring

Several houses and portable classrooms are being monitored and the data displayed on the web. (Visit http://www.infomonitors.com/). Of special interest is the side-by-side monitoring of two manufactured homes on the campus of the North Carolina A & T U. where the advanced home is saving about 70% in heating energy and nearly 40% in cooling energy, proving that the Building America goal can be met in manufactured housing. Other monitored sites include the Washington State U. Energy House in Olympia, WA; the Hoak residence in Orlando, FL; two portable classrooms in Marysville, WA; a classroom each in Boise, ID and Portland, OR. See other papers being presented at this symposium for details on two recently completed projects giving results from duct repairs in manufactured homes (Withers et al) and side by side monitoring of insulated concrete form and base case homes (Chasar et al).

"Cool" Roofs and Unvented Attics

Seven side-by-side Habitat homes in Ft. Myers, FL. were tested under unoccupied conditions to examine the effects of alternative roofing strategies. After normalizing the data to account for occupancy and minor differences in thermostat set points and equipment efficiencies, the sealed attic saved 9% and the white roofs saved about 20% cooling energy compared to the base case house with a dark shingle roof for the summer season in South Florida. Visit http://www.fsec.ucf.edu/%7Ebdac/pubs/coolroof/exsum.htm for more information.

Habitat for Humanity

Habitat for Humanity affiliates work in the local community to raise capital and recruit volunteers. The volunteers build affordable housing for and with buyers who can't qualify for conventional loans but do meet certain income guidelines. For some affiliates, reducing utility costs has become part of the affordability definition.

To help affiliates make decisions about what will be cost effective for their climate, BAIHP researchers have developed examples of Energy Star homes for more than a dozen different locations. These are available on the web at http://www.fsec.ucf.edu/bldg/baihp/casestud/hfh_estar/index.htm . The characteristics of the homes were developed in conjunction with Habitat for Humanity International (HFHI), as well as Executive Directors and Construction Managers from many affiliates. Work is continuing with HFHI to respond to affiliates requesting a home energy rating through an Energy and Environmental Practices Survey. 36 affiliates have been contacted and home energy ratings are being arranged using combinations of local raters, Building America staff, and HFHI staff.

HFHI has posted the examples of Energy Star Habitat homes on the internal web site PartnerNet which is available to affiliates nationwide.

"Green" Housing

A point based standard for constructing green homes in Florida has been developed and may be viewed at http://www.floridagreenbuildings.org/. The first community of 270 homes incorporating these principles is now under construction in Gainesville, FL. The first home constructed and certified according to these standards has won an NAHB energy award.

BAIHP researchers are participating as building science - sustainable products advisor to the HUD Hope VI project in Miami, redeveloping an inner city area with over 500 units of new affordable and energy efficient housing.

Healthy Housing

BAIHP researchers are participating in the development of national technical and program standards for healthy housing being developed by the American Lung Association.

A 50-year-old house in Orlando is being remodeled to include energy efficient and healthy features as a demonstration project.

EnergyGauge USA®

This FSEC developed software uses the hourly DOE 2.1E engine with FSEC enhancements and a user-friendly front end to accurately calculate home energy ratings and energy performance. This software is now available. Please visit http://energygauge.com/ for more information.

Industrial Engineering Applications

The UCF Industrial Engineering (UCFIE) team supported the development and ongoing research of the Quality Modular Building Task Force organized by the Hickory consortium, which includes thirteen of the nation's largest modular homebuilders. UCFIE led in research efforts involving factory design, quality systems and set & finish processes. UCFIE used research findings to assist in the analysis and design of two new modular housing factories – Excel homes, Liverpool, PA and Cardinal Homes - Wyliesburg, VA.

CONCLUSIONS

The entire BAIHP team of over 20 researchers and students are involved in a wide variety of activities to enhance the energy efficiency, indoor air quality and durability of new housing and portable classrooms.

In addition to energy efficiency, durability, health, comfort and safety BAIHP builders typically consider resource and water efficiency. For example, in Gainesville, FL BAIHP builders have incorporated the following features in developments:

- Better planned communities
- More attention given to preserving the natural environment
- Use of reclaimed sewage water for landscaping
- Use of native plants that require less water
- Storm water percolating basins to recharge the ground water
- Designated recreational areas
- Better designed and built infrastructure
- Energy efficient direct vented gas fireplaces (not smoke producing wood)

ACKNOWLEDGEMENTS

This research was sponsored, in large part, by the U.S. Department of Energy, Office of Building Technology, State and Community Programs under cooperative agreement no. DE-FC36-99GO10478 administered by the U.S. DOE Golden field office. This support does not constitute an endorsement by DOE of the views expressed in this report.

The authors appreciate the encouragement and support from George James, program manager in Washington DC and Keith Bennett, project officer in Golden CO.

Special thanks to Bert Kessler of Palm Harbor Homes, Mike Dalton of Stylecrest Sales, Mike Wade of Southern Energy Homes and David Hoak of Alten Design for the hundreds of hours they have each contributed to the success of BAIHP.

We are grateful to our sponsors, industry partners, collaborators and colleagues for this opportunity to make a difference.

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